BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: Summary Review of Data Relay Satellite System Program - Case 320

DATE: July 5, 1967

FROM: R. K. Chen

ABSTRACT

The background and history of the Data Relay Satellite System (DRSS) concept for the direct relay of information between an orbiting spacecraft and the Mission Control Center (MCC-H) by a communication satellite is reviewed. The results of two "Phase A" study contracts on this type of system are evaluated. These contracts were let by the Office of Tracking and Data Acquisition (OTDA) and were completed in March 1967. From the study results, the conclusion is that an operational DRSS using a retrodirective phased array antenna system is feasible; it would support two Apollo-like space vehicles simultaneously and continuously with a wideband data relay capability. A gross cost comparison indicates that the total program cost of the DRSS system over a ten year period would be 250 million dollars less than the cost of operating and maintaining the present Manned Space Flight Network (MSFN) excluding the deep space stations. Several gaps of knowledge remain to be filled for the DRSS design, namely:

(1) mechanical packaging and antenna deployment techniques,

(2) satellite stabilization and station keeping techniques, and

(3) magnitude of multipath problems between an orbiting space vehicle and the relay satellite.

It is suggested that several NASA projects now being planned could be oriented to complement DRSS and supply needed data; these projects are: (1) ATS F-G, (2) large erectable antenna study, and (3) the ATS-1 and LM Relay experiments proposed for AAP missions.

FACILITY FORM 602
[redacted]
(ACCESSION NUMBER) (THRU)
22 84
(PAGES) (CODE)
CR-87750

(NASA-CR-154813) SUMMARY REVIEW OF DATA RELAY SATELLITE SYSTEM PROGRAM (Bellcomm, Inc.) 22 p

N79-72169

Unclas
00/15 12516

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Summary Review of Data Relay Satellite System Program - Case 320

DATE: July 5, 1967

FROM: R. K. Chen

MEMORANDUM FOR FILE

I. Background

The Data Relay Satellite System (DRSS), previously called the Orbiting Data Relay Network (ODRN), is conceived as a communication system using satellites located in earth synchronous orbits to permit two-way communications service between space vehicles and the Mission Control Center (MCC-H). The concept evolved from the desire to use communication satellites to augment the coverage of Manned Spaceflight Network (MSFN) for the purpose of providing continuous communication between space vehicles and MCC-H, and thereby improving the effectiveness of mission operations and reducing the cost of the MSFN.

The possibility of using a satellite as a communication relay between an orbiting spacecraft and a ground station was discussed by Speake in 1964[1]. This suggestion involved voice links only because of the limited capacity of the first generation communication satellites, such as Telstar and Syncom. A similar application involving voice communication links between an aircraft and ground station was also studied; again, the satellites considered were of the Telstar, Syncom, and Early Bird types. With the results of these studies, it became clear then that (1) although the communication satellite technology was advancing rapidly most of the development effort was directed towards a high communications capacity application between ground terminals, and (2) an entirely different class of communication satellite would be needed to accomplish the direct relay function between a spacecraft and a ground station. A study was initiated at Bellcomm to define the gross parameters of a direct relay satellite system based on the communication requirement of Apollo vehicles.[5]

The preliminary results of the Bellcomm study[6] were presented during a June 17, 1965 meeting held at NASA Headquarters. Requirements for the implementation of communication satellite systems to support manned space flight operations were discussed between representatives from OMSF, OTDA, OSSA,

Available to NASA Offices and Research Centers Only.

MSC, GSFC, and Bellcomm. The operational advantages of such a system were also discussed during the presentations by Messrs. D. E. Fielder and W. A. Lee of MSC and by Mr. J. J. Hibbert of Bellcomm. The major advantages stated included:

(1) Continuous centralized mission control by MCC-H,

(2) Mission design flexibility for Earth orbital mission phases by avoiding the constraint of conducting critical phases of the mission within the line of sight of MSFN stations,

(3) Additional flexibility in determining the beginning of missions by avoiding the lead time now required to deploy personnel, ships, and aircraft,

(4) Continuous contact with the spacecraft during aborted missions as well as during nominal missions,

(5) Communication with the spacecraft after landing to facilitate quick recovery,

(6) Increased coverage of high inclination orbit missions, and

(7) Deactivation of many of the MSFN sites used for near Earth mission phases.

As the result of the meeting, OMSF requested OTDA to initiate "phase A" studies for the DRSS (ODRN) concept.

In the following, the two DRSS Phase A study contracts are described in Section II. In Section III, the results of a technical review of the DRSS studies are presented, cost comparisons are made between the present MSFN and DRSS, and potential problem areas are mentioned where further studies are indicated. Section IV enumerates several NASA projects currently in planning stages which may contribute to or complement the DRSS program. Section V presents the conclusions and recommendations for the continuation of the DRSS program.

II. DRSS Study Contracts

Mr. P. F. Barritt of OTDA was assigned as the technical contract monitor for the DRSS studies. Under his coordination, a work statement for the study was drafted and finalized with inputs from OMSF and OSSA. The final "Statement of Work" which was Article III of the contract is included in this memorandum as Appendix A. Two contractors were selected to perform the study, they were (1) Astro-Electronics Division of RCA, and (2) Lockheed Missile and Space Company. The studies were initiated during August 1966, and completed during March 1967.

It should be noted that the scope of these studies was somewhat restricted as indicated by the underlined portions of Appendix A.* As the result of these restrictions, portions of the total system feasibility study were purposely left out, namely, the mechanical design and packaging of the satellite and the analysis of the spacecraft stabilization and station keeping techniques. In addition, the contractors were instructed to adapt the use of a multi-beam electronically steered phased array as the satellite antenna. The omissions made at the time were partially motivated by the desire of obtaining such information from the Advanced Technology Satellite (ATS-4**) program which was in the planning stage at OSSA. Specifically, ATS-4, as planned at that time, would involve the deployment of a large antenna (30 ft. parabolic dish) that has a pointing capability and is stabilized in all three axis in a synchronous orbit.

III. DRSS Study Results

Upon the completion of the studies, the contractors have provided their findings and conclusions in written final reports [7,8]. These reports have been reviewed.[9] In the following the technical portion is extracted from Reference 9 and the cost portion is extracted directly from the reports.

A. Technical Review

As instructed by the work statement of the contract, both studies evaluated various satellite repeater design concepts compatible with the usage of phased array antennas. A common conclusion was reached that the most desirable system would be a retrodirective phased array antenna and repeater. The study made by RCA also included the capability of deriving tracking information from an orbiting space vehicle through the relay satellite. Another common agreement is that the coverage

*The underlines were added by the writer, they did not appear in the original contract.

**ATS-4 is now known as ATS F-G

capability of the relay satellite should be restricted to lower altitude space vehicles (less than 2,000 nm) because of the exponential growth in satellite weight with the coverage at increasing altitude. Although the proposed repeater and antenna design has never been adapted for space applications, both contractors felt that the design and implementation of such a system would be technically feasible. However, in order to achieve a light weight design in practice, improvement in the present technology would be needed.

A three satellite system was proposed for the operational system with two ground terminals required. One ground terminal would be situated near MCC-H, and the other ground terminal located in Australia. The second terminal is necessary to serve as a satellite-to-satellite relay terminal because one of the three satellites is not visible from the continental U.S. A method of incorporating a satellite-to-satellite relay for the purpose of deleting the second ground terminal was discussed by Lockheed; it is felt that such a system would greatly increase the complexity of the satellite design, both electronically and mechanically, and to render it unattractive.

Certain portions of the studies are lacking in depth of analysis; especially the system requirements and performance required for RF acquisition. The proposed design of the phase-locked loop circuit is believed to be inadequate considering the magnitudes of doppler frequencies that will be encountered by the system. Moreover, under severe multipath conditions between the orbiting space vehicle and the satellite, the predicted system performance would be even more questionable. It is possible to alleviate some of the multipath problem in operation by proper handover, however, the limiting conditions and the severity of the problem are not entirely clear.

With the limited satellite coverage as proposed by both studies, it may be well to consider other antenna designs that would provide equal electrical performance. The utilization of a reflector type antenna using a phased array feed may prove to weigh less and be simpler to implement mechanically.

It should also be mentioned that a two satellite system could be used with some sacrifice in coverage. By locating two ground stations, one at the East Coast of the United States and one at the West Coast of the United States, over 80 percent of world-wide coverage is obtainable. The coverage gaps for low altitude earth orbits would last for approximately 10 minutes or less over the Indian Ocean and the continental United States. The advantage of this system is that the overseas ground station needed for the three satellite systems is no longer required; consequently, the satellite-to-satellite relay link would not be necessary either.

B. Cost Comparison

The cost for a fully operational DRSS has been estimated by RCA and Lockheed. It is not possible to make a direct comparison between the two estimates in cost distributions; however, the total program cost can be compared as follows:

RCA	$ 160 million
Lockheed	$ 163 million - 209 million

These costs include: (1) the research and development, (2) initial deployment for a three satellite system including the launch vehicle (approximately $54 million for Atlas-Centaur), and (3) two ground terminals. The $ 209 million figure from the Lockheed report also includes two additional full scale flight tests prior to the deployment of the operational system. The yearly cost for operating the DRSS was estimated as follows:

RCA	$ 18.8 million
Lockheed	$ 11.1 million

These costs include ground station operation, and replenishment of the satellites if required. The principal difference between the two costs is the estimate of the replenishment cycle for the satellites. RCA's estimate was based on a satellite design of 5 year mean-time-to-failure (MTTF), while Lockheed's estimate was based on a 10 year MTTF design. In addition to the cost above, approximately $ 8 million per year should be added which represents the communication cost of ground-to-ground relay of two video channels via common carrier.

The deployment of an operational DRSS would eventually make some of the MSFN stations expendable. It is, therefore, a natural tendency to compare the cost difference between a DRSS and the MSFN. Such a comparison would not be valid as the two systems are vastly different in terms of total real time information transfer capabilities and effectiveness in operations for manned space flight. Nevertheless, it is instructive to compare the two systems on the dollar basis for long term budget planning purposes. Based on gross estimates obtained from OTDA the cost of the present MSFN excluding those stations equipped with 85 ft. antennas are as follows:

<u>Initial Cost</u> (per unit)

30 ft antenna station	$ 10 million
Ship (Insertion and Injection)	$ 40 million
Ship (Reentry)	$ 20 million
Aircraft (ARIA)	$ 4.5 million

Annual Operating Cost

30 ft antenna station (per station)	$ 1.3 million
Ships (5 ships)	$ 20 million
Aircraft (8)	$ 6.0 million
Communications	$ 33 million

In total, the initial cost for MSFN, including eleven 30 ft antenna stations, five ships, and eight aircraft, is approximately $ 306 million, and the annual operating cost is $73.3 million.

The total program cost over a ten year period for the MSFN and a DRSS, using the higher cost estimates for the DRSS, are as follows:

MSFN (excluding 85 ft antenna stations)	$ 1,039 million
DRSS	$ 477 million

The total program cost (investment plus operating) per year for the DRSS, averaged over a ten year period, is compared with the annual operating cost of various combinations of MSFN stations excluding the capitol expenditure as follows:

MSFN (including ships and aircraft but excluding 85 ft. station)	$ 73.3 million
MSFN (ships, aircraft, Canary Island, Ascension Island, and Carnarvon)	$ 52 million
DRSS	$ 47.7 million
MSFN (ships and aircraft only)	$ 33 million

It is interesting to compare the anual cost of the DRSS with those for ships and aircraft, and ships and aircraft plus Canary, Ascension, and Carnarvon. These stations are selected because they are either mobile stations with high initial and operating costs or they are ground stations where satellite circuits are used for network communications. It should also be noted that the MSFN cost figure allows limited numbers of communication channels to be transmitted from overseas stations; at present, six data/voice channels plus two teletypewriter channels are configured for each station. Moreover, for future missions, communication channel requirements from the overseas stations will increase.

C. Undefined Areas

As discussed previously, the DRSS contractual studies did not include any spacecraft design considerations except for the electronics portion. Consequently, two major areas of the satellite design would need to be established, they are (1) the mechanical packaging and antenna deployment technique, and (2) the analysis and design of stabilization and station keeping techniques. A possible start for these points is discussed in the following section.

IV. Related Projects

Several NASA projects which are either in progress or in planning stages can be classified as similar to the DRSS functionally, operationally, or complementary in technological development. These projects are discussed in the following.

A. ATS-1 VHF Experiment

The ATS-1 satellite, launched during December 1966, is a spin stabilized communications satellite situated at approximately 151° W longitude above the equator in a synchronous orbit. It carries a VHF repeater (up-link 149.22 MHz, down-link 135.6 MHz) with a 100 kHz RF bandwidth for the primary purpose of providing a two-way voice relay circuit between an aircraft in-flight and ground terminals. Considerable ground-ground and aircraft-ground experiments have been performed with ATS-1, and some of the results have been published.[10] Preliminary results indicate that when the aircraft transmits 200 to 500 watts of effective radiated power (ERP, which is the product of transmitter power and antenna gain), the voice qualities are acceptable to good. The ATS-C satellite is planned to be launched in late 1967 and will be situated in a geostationary orbit over the Atlantic Ocean. It will carry a VHF repeater similar to that of ATS-1. The Saturn/Apollo Applications Program has requested McDonnell Company[11, 12, 13] to "initiate a study to consider the installation of appropriate terminal equipment on the Airlock Module to permit utilization of the ATS VHF communications relay and advise of the resulting implications".[13]

If the ATS VHF relay links could be utilized in the AAP missions, the following experience can be derived to benefit the DRSS program, namely:

(1) The operational experience with an orbiting manned vehicle when in near continuous contact with MCC-H by voice or low bit rate telemetry.

(2) A gross assessment of possible multipath problems between the spacecraft and the relay satellite.

B. LM Relay Experiment

A "LM Relay Experiment" has been proposed by Mr. S. W. Fordyce of Apollo Applications Office (MLA) as one of the experiments to be carried on a synchronous Apollo Applications mission.[14] The communication functions desired are two-way voice, up-data, low bit rate (1.6 kbps) telemetry, and range and range rate tracking. The experiment proposal is now in the feasibility study and system definition phases; the status of the project is included in this memorandum as Appendix B. The purposes of this experiment are (1) to demonstrate the use of a tracking and communication relay between an orbiting CSM and MSFN, and (2) to provide the experience in flight operations with such a relay. The ground rules for this experiment are:

(1) Minimum (preferably no) modifications to MSFN stations.

(2) Minimum cost, utilize standard Apollo Unified S-band equipment (USB) wherever possible.

(3) Experimental equipment on the spacecraft to be independent of the operational equipment.

(4) With successful completion of the experiment, the relay should be capable of providing long term (one year) operational use.

If the LM Relay Experiment were approved for an AAP synchronous mission and operated successfully, the following experience can be derived to benefit the DRSS program.

(1) Sufficient operational experience can be derived with the improved communication capabilities over the ATS VHF experience so that requirements for manned space flight operations can be refined for cases when continuous communication coverage is available.

(2) A better assessment of possible multipath problems between the spacecraft and the relay terminal.

(3) Determine the effectiveness of obtaining tracking data on an orbiting spacecraft through a satellite relay.

(4) Possibility of using the relay terminal as a test bed for a small size retrodirective phased array antenna.

C. <u>ATS F-G</u> (planned not approved)

The mission objectives abstracted from Reference 15 for the ATS F-G are as follows:

"To provide research, development, and flight testing common to a number of applications, and early testing of promising items, several to each individual spacecraft. To conduct experiments in active or mixed stabilization techniques as applied to large rotatable masses, within stabilization accuracies of ±0.1 degree or less and with lifetime of two years or more. Certain specific technology intimately connected with requirements for stabilization of this accuracy would be flight tested as a part of the experiments. This would include: (1) deployment and pointing of large antennas (9 m aperture), (2) pilot beam pointing of high gain (30-45 dB) phased array antennas including multiple beam formation, (3) . . ."

It is clear, from the description above, ATS F-G satellites would be compatible with the DRSS program for the purposes of providing test flights to determine practical stabilization techniques and mechanical deployment methods for large phased array antennas.

(D) <u>Large Space Erectable Antenna Study</u>

Convair Division of General Dynamics Corp. (GD/C) has recently completed a feasibility study for OMSF/OSSA on large space erectable antennas. From the summary of the final report[16] three antenna configurations are recommended. One of them is a large phased array antenna. The entire structure consists of seven hexagonal panels with a total area of approximately 350 square feet when unfolded. OSSA is presently planning on negotiating with GD/C to extend the study.[17] Conceivably, the extended study can be oriented toward the retrodirective phased array configuration from the DRSS studies.

(V) Conclusions and Recommendations

The advantages of continuous communications coverage afforded by a DRSS for manned spaceflight operations were recognized prior to the contract studies. With the completion of the Phase A studies, the cost effectiveness of the system and the feasibility, at least the non-mechanical portion, can be summarized as follows:

(1) The retrodirective phased array antenna proposed for DRSS satellites has the principal advantages of (a) a multiple beam forming capability, (b) not requiring mechanical steering, and (c) graceful degradation in performance with array component failures.

(2) It is practical to use a phased array antenna for communications coverage of space vehicles at altitudes below 2000 nm.

(3) A light weight array design would require some forcing of the present technology, but appears feasible.

(4) The cost, including investment and operating, of a DRSS system is approximately 250 million dollars less, over a ten year period, comparing it with the cost of maintaining and operating the present MSFN stations (equipped with 30 ft. antennas), ships, and aircraft.

(5) Over and above the cost saving, the DRSS could provide transmission capability of four simultaneous 10 MHz RF channels on the down link continuously, which would not be possible with ground network configurations.

(6) Multipath could be a problem between the orbiting space vehicle and the relay terminal. The magnitude of this problem has not been clearly defined. More detailed analysis appears to be advisable.

(7) Since antenna design was not part of the DRSS tradeoff study, it appears that such a study should be made between a retrodirective phased array antenna and other antenna configurations such as a parabolic antenna with an electronically scanned array feed.

With the results of the DRSS studies and the assessment of other NASA programs, it is recommended that the following steps be taken for the continuation of the DRSS program:

(1) Initiate a detailed analytical study of the multipath problem between an orbiting space vehicle and the relay terminal.

(2) Initiate a tradeoff study to determine the relative advantages between the proposed retrodirective phased array antenna and other antenna designs including a dish antenna with an array feed. This could be a follow on study to the completed DRSS studies.

(3) Initiate a Phase B or Phase C study on a small retrodirective phased array antenna design with the objective that it would be applicable for a larger size array.

(4) Initiate a study on the possible frequency allocation problem for an operational DRSS.

In view of the lack of spacecraft design studies for the DRSS, the following steps are suggested:

(1) Coordinate with OSSA to determine the advisability of including the mechanical deployment method of the retrodirective antenna array as part of the follow on study to the completed large space erectable antenna study by General Dynamics Corp.

(2) Coordinate with OSSA on the necessary steps to be taken so that the Advanced Technology Satellite (ATS F-G) program would be complementary with the DRSS program.

(3) Orient either or both the ATS-1 and LM Relay Experiment suggested for AAP missions so that the necessary operational experience and multipath data between the manned space vehicle and the relay terminals can be obtained.

(4) Develop a comprehensive and complementary schedule for DRSS and related programs so that an orderly development cycle can be realized which would lead to a fully operational DRSS at the earliest possible date.

2034-RKC-jad R. K. Chen

Attachments
Appendices A & B

APPENDIX A

STATEMENT OF WORK OF NASW 1447

The work shall include the following tasks:

A. Determine the optimum configuration of the ODRN as a system; i.e.,the number and location of relay satellites and ground stations to maximize the operational capability of the system while minimizing over-all cost, including the cost of common carrier circuits between ODRN ground stations and the mission control centers at Pasadena, California; Greenbelt, Maryland; and Houston, Texas.

An analysis should be made of the capabilities of systems having two orbiting relay satellites (known to have coverage gaps) and of systems having three or more relay satellites. In connection with systems having three or more relay satellites, the Contractor should investigate the practicability of using one or more of the relay satellites to provide "double hop" service from the western Pacific Ocean and the Indian Ocean, i.e. consider a link from spacecraft to relay satellite to a ground station in the western Pacific area, back through a second relay satellite to the continental United States.

B. Conduct parametric studies to permit trade-offs in areas of relay satellite antenna size, repeater design, payload weight, power supply capacity, etc., in terms of the support capability of the ODRN. The Contractor should, based upon his best estimate of the trade-offs, recommend an overall system configuration and generate a preliminary electronics system design for both the relay satellites and the ground stations. The following limits on target vehicle parameters may be assumed:

1. There may be two target vehicles (not close enough together to be within the same antenna beam) requiring simultaneous support by a single relay satellite.

2. Each target vehicle may have up to two transmitters and two receivers.

3. The transmissions from target vehicle to relay satellite will be either:

a. FDM/FM with a maximum multiplexed base bandwidth of 1.5 mc/s and a maximum peak deviation for the multiplexed signal of 3.5 mc/s.

b. PCM/PM with a maximum data rate of 1,000,000 bits/second at a 10^{-6} bit error rate (BER).

Each target vehicle may transmit in one of each of the above modes or two of either kind.

4. The target vehicle can carry a small directional antenna having a maximum gain of 20 db (including line losses).

5. Transmissions to the target vehicle will be either:

a. FDM/FM with a maximum multiplexed base bandwidth of 150 Kc/s and a maximum peak deviation for the multiplexed signal of 350 Kc/s.

b. PCM/PM with a maximum data rate of 100,000 bits/second at a 10^{-6} bit error rate (BER).

Each target vehicle may receive in one of each of the above modes or two of either kind.

6. The target vehicle receivers will be of the type used in the present NASA Unified S-Band (USB) system.

7. The target vehicle receiver noise figure will be no better than 10 db.

8. The frequency bands to be used are as follows:

a.	Target vehicle to relay satellite	2210-2300
	Relay satellite to target vehicle	2100-2120/ 1760-1850
	Ground to relay satellite	8310-8400
	Relay satellite to ground	7660-7750
b.	Target vehicle to relay satellite	8410-8500
	Relay satellite to target vehicle	7660-7750
	Ground to relay satellite	2100-2120/ 1760-1850
	Relay satellite to ground	2210-2300
c.	Target vehicle to relay satellite	8410-8455
	Relay satellite to target vehicle	2255-2300
	Ground to relay satellite	2100-2120/ 1760-1805
	Relay satellite to ground	2210-2255

d. For point-to-point communications (communications satellite mode)

Ground to relay satellite	2090-2100/ 1750-1760
Relay satellite to ground	2200-2210

C. The design of the antennas is not part of this contract. It is the responsibility of the Contractor, however, to define some of the characteristics required, such as acquisition procedure, tracking rates required, and limits. The final size of the apertures will be determined as a function of NASA's ultimate needs and the state-of-the-art. For purposes of this study, it should be assumed that it is possible to use an antenna with at least a 30-foot aperture. Furthermore, since multiple target tracking is desired, it should be assumed that the antenna used is a multiple beam electronically phased array. The Contractor is to investigate the impact of various means of achieving multiple beam capability on the design of the repeater electronics.

D. The complete ODRN system is to have a reliability of 0.998. The Contractor is to determine the requirements for redundancy of relay satellites, redundancy of equipment within the relay satellites and ground stations, relay satellite replenishment cycles, and ground station maintenance to achieve the required reliability. In this instance, 0.998 reliability is defined as a 99.9 per cent probability that the system will be operational at any time it is required. It should be assumed that the system will be in continuous use for periods of of up to 30 days with a maximum of one idle day between periods of use.

E. Provide an estimate of the cost of implementing and operating the resultant ODRN, including the cost of common carrier circuits between the ODRN ground stations and the mission control centers.

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6
UNITED STATES GOVERNMENT

Memorandum

APPENDIX B

TO : Distribution

DATE: MAR 13 1967

FROM : MLA/S. W. Fordyce

SUBJECT: Status of the LM Relay Experiment

INTRODUCTION

The LM Relay Experiment (1) proposes placing equipment on a manned spacecraft planned for an earth synchronous orbit to serve as a communications and tracking relay between two terminals. One of these terminals is a manned spacecraft (the "cluster") in a low altitude orbit, and the other is the Manned Space Flight Network (MSFN).

This experiment can provide a capability for continuous communication and tracking of manned spacecraft over half (45 minute) of their orbits rather than the 5-10 minute intervals available with the present MSFN. If operational experience proves this experiment successful, such relays may replace some of the mobile and fixed stations of the MSFN.

DEFINITION PHASE

The present definition phase is intended to complete the definition and design of the experiment by July 1967. Efforts underway within NASA have included such tasks as the:

MSFC in-house effort under the direction of Tom Barr, which was completed on February 10, and led to significant improvements in the experiment definition.

MSC in-house effort under the direction of Bill Gatling, which is defining the operational requirements of the experiment.

Contractor efforts which are underway include:

Bellcomm's Systems analyses and signal margin calculations by Bob Chen and Bob Selden. (2)

Motorola - A laboratory simulation of the modes described in reference 1 using phase locked loop transponders. This contract (3) is under the technical direction of Paul Shores and Meridith Hamilton of MSC and is being run at Motorola by John Barto and Bob Hunting. Hopefully, this work will prove the feasibility of using either a series chain of phase locked loop transponders described in reference 2 as the "ring-around" mode, or a dual pair of phased loop locked transponders with interconnections in the relay. At the completion of this work Motorola will recommend a mode and demonstrate its operation. The next review at Motorola will take place on March 30th and 31st.

Hughes Aircraft Company - A design of the experiment modes using frequency translation repeaters in the direction of Dick Houghton of Hughes, and is being monitored through Lee Malone of MSFC. The next review at Hughes is scheduled for the morning of March 31st.

Bissett-Berman Corporation - A tracking study (5) to evaluate the capabilities of a network of synchronous relays to determine the orbital parameters of a low altitude orbiting spacecraft and replace certain of the mobile and fixed stations of the MSFN. This study is under the direction of Herman Epstein of Bissett-Berman, and is being monitored by Sam Fordyce of NASA Headquarters. A review will take place at Bissett-Berman on the afternoon of March 31st.

Dalmo Victor Corporation - A design (6) of improved spacecraft antennas to permit wider band width signals to be sent via the LM Relay. This study will be directed by Don Stoddard of Dalmo Victor, and be monitored by Jim Kelley of MSC. A review will take place at Dalmo Victor on April 3rd.

This completes a brief review of the status of the LM Relay Experiment. Copies of all references can be made available upon request. Efforts are underway to coordinate this work with related efforts within NASA to permit an early demonstration of a voice relay (through an ATS Satellite), and to provide greater growth capability (using a high gain phased array antenna on the Relay as proposed by the Orbital Data Relay Network Study).

Samuel W. Fordyce

Samuel W. Fordyce
Principal Investigator,
LM Relay Experiment

References

1. S. W. Fordyce, "LM Relay Experiment" NASA form 1138, October 12, 1966 revision.

2. R. K. Chen & R. L. Selden, "Expected Communications Performance for the Proposed LM Relay Experiment," TM 67-2034-2, Bellcomm, Inc., January 19, 1967.

3. Paul Shores, Motorola Work Statement on LM Relay Experiment, NASA-MSC.

4. Lee Malone, Hughes Aircraft Company Work Statement on LM Relay Experiment, NASA-MSFC, amended March 7, 1967.

5. Herman Epstern, "LM Relay Experiment Tracking Study," Bissett-Berman Corportion, February 27, 1966.

6. Paul Shores, Dalmo Victor Work Statement on LM Relay Experiment, NASA-MSC.

REFERENCES

1. G. H. Speake, "Satellite Communications Between Spacecraft and Manned Spaceflight Network", Bellcomm Memorandum for File, July 15, 1964.

2. E. M. Coombs, "Satellite Relay at VHF Between Aircraft and Manned Spaceflight Network", Bellcomm Memorandum for File, March 29, 1965.

3. E. J. Linger and J. M. Trecker, "Project Apollo - Aircraft - Ground Communication Using Synchronous Orbit Satellite Radio Relay", Memorandum for File, Bell Telephone Laboratory Inc., June 9, 1965.

4. E. J. Linger and J. Trecker, "Project Apollo - Aircraft - Ground Communication Using 6000 nm Altitude Satellite Radio Relay", Memorandum for File, Bell Telephone Laboratories, Inc., April 2, 1965.

5. R. K. Chen, E. M. Coombs, J. P. Maloy and G. H. Speake, "Direct Communication Satellite Relay between Apollo - like Space Vehicles and the Mission Control Center", Bellcomm Technical Memorandum, #65-2021-9, December 29, 1965.

6. J. J. Hibbert, "Presentation on Communicating Total Data From Space Vehicles to MCC in Real Time", Bellcomm Memorandum for File, July 27, 1965.

7. "Final Report, Orbiting Data Relay Network", prepared by Astro-Electronics Division, RCA, Princeton, N. J., Report #AED R-3152, March 22, 1967.

8. "Final Report, Orbiting Data Relay Network Study", prepared by Lockheed Missile & Space Co., Sunnyvale, California, Report #LMSC-699559, April 10, 1967.

9. E. J. Klein, "Technical Review of Final Reports for Orbiting Data Relay Network Studies", Bellcomm Memorandum for File, to be published.

10. "VHF Repeater Experiment, Final Report", Hughes Aircraft Co. Report #SSD 70041R, February 1, 1967.

11. "Synchronous Communications & Tracking Relays on the AAP", Memorandum from S. W. Fordyce/MLA to C. W. Mathews/ML, March 27, 1967.

12. Letter from Mr. C. W. Mathews/ML to Mr. R. F. Thompson/MSC/KA, Dated March 20, 1967.

13. Letter from K. F. Hecht, Manager Orbital Workshop Project, MSC to W. F. Burke, President, McDonnell Astronautics Co., Dated March 28, 1967.

14. S. W. Fordyce, "LM Relay Experiment Proposal, NASA Form 1138, Revision dated October 12, 1966.

15. "OSSA Prospectus 1966, Appendix B, Description of Present and Projected Projects", September 1966 edition, For Official Use Only.

16. "Feasibility Study of Large Space Erectable Antennas", Vol. 1, Executive Summary, NASA Contract NASW 1438, prepared by Convair Division of General Dynamics, San Diego, California, February 28, 1967.

17. Private Communication with Mr. A. M. G. Andrus/SAC May 9, 1967.

BELLCOMM, INC.

Subject: Summary Review of Data Relay Satellite System Program

From: R. K. Chen

Distribution List

NASA Headquarters

Messrs. A. M. Andrus/SAC
B. P. Brown/MOR
S. W. Fordyce/MLA
J. K. Holcomb/MAO
T. A. Keegan/MA-2
J. T. McClanahan/MAO
W. E. Miller/MOG
J. D. Stevenson/MO
G. M. Truszynski/TD
J. H. Turnock/MA

MSC

Messrs. C. A. Beers/FC
D. E. Fielder/FA-4 (5)
J. D. Hodge/FC
C. C. Kraft/FA
H. C. Kyle/EB
W. A. Lee/PA
D. H. Owens/FC
L. Packham/EE
P. Vavra/EB

Bellcomm

Messrs. G. M. Anderson
W. J. Benden
A. P. Boysen, Jr.
D. R. Hagner
P. L. Havenstein
J. J. Hibbert
B. T. Howard
W. C. Hittinger
J. E. Johnson
E. J. Klein
H. Kraus
J. P. Maloy
J. Z. Menard
I. D. Nehama
B. F. O'Brien
J. T. Raleigh
I. M. Ross
N. W. Schroeder
R. L. Selden
G. H. Speake
W. Strack
R. L. Wagner
A. G. Weygand
W. D. Wynn
Department 1023
Central Files
Library